4. Estimation of Reserves

- Estimation of oil and gas reserves in a discovered reservoir is one of the most important factors in evaluating the discovery and deciding on its viability for commercial development.
- The numbers for factors are established by conducting a series of test drills around the reservoir.

4.1. Initial oil in place (IOIP)

- Methods of estimating the reserves are **volumetric method**, **the material balance method** and **decline curve method**).
- To determine the volume of oil or gas present in the reservoir, the bulk volume of the reservoir (V_b) is first determined.
- The volume of fluids in the pore spaces of the reservoir rock is then calculated by multiplying the bulk volume by the rock porosity ($\boldsymbol{\Phi}$); this is also known as the pore volume of the rock.
- The pore volume (V_b) is normally occupied by oil (or gas) and water. The fraction of the pore volume occupied by water is known as the water saturation (S_w). Therefore, the initial volume of oil (V_0) at the reservoir conditions is determined by:

$$V_0 = V_b \boldsymbol{\Phi}\, S_o = V_b \boldsymbol{\Phi}(1 - S_w).$$

- This volume of oil is called **the initial oil in place (IOIP) or the original oil in place (OOIP).**
- This method for estimating IOIP is the volumetric method.
- Initial oil in place (IOIP) is the amount of crude oil first estimated to be in a reservoir.
- Oil initially in place differs from oil reserves, as IOIP refers to the total amount of oil that is potentially in a reservoir and not the amount of oil that can be recovered.
- It is impossible to recover all of the OOIP; certain forces within the reservoir rock prevent the movement of some oil from the rock to the well.
- As written, the equation above of OOIP gives the volume of oil at reservoir conditions. To obtain oil volume at stock tank conditions (A STB is the same volume defined at some surface

standard conditions (in the stock tank) which are usually 60°F and 14.7 psi), the formation volume factor for oil B_o must be included:

$$V_o = \frac{Ah\,\Phi\,(1-S_W)}{B_o}\,\frac{1\text{bbl}}{5.6148\ \text{ft}^3}$$

Where: V_o is OOIP in STB, A is reservoir area in (ft^2), h is reservoir thickness (ft), Φ is porosity (fraction), S_w water saturation (fraction) and B_o is oil formation volume factor RB/STB.

- If reservoir area measured in (Acres), the equation is written as:

$$V_o = \frac{7758\,Ah\,\Phi\,(1-S_W)}{B_o}$$

- When referring to liquid volumes at stock tank conditions, we use the units of ***Stock Tank Barrels*** (STB).
- **The oil formation volume factor (B_o)** is defined as the ratio of the volume of oil (plus the gas in solution) at the reservoir temperature and pressure to the volume of oil at standard conditions. B_o is always greater than or equal to unity.
- The oil formation volume factor is expressed in units of reservoir volume over standard volume (usually RB/STB).
- At surface, the oil loses the dissolved gas it contained under high pressure and temperature in the reservoir.

4.2. The Proven Reserves.

The fraction of the volume of oil produced or capable to produce and the volume of the original oil is called **the recovery factor (R_f)**, and the total recoverable volume of oil ($R_f\,V_0$) is called **the proven reserves**.

$$\text{Proven reserves} = \text{IOIP} * R_f$$

The proven reserve for a reservoir is changed with time as a result of three factors:

1- The volume of oil in place decreases as oil is produced from the reservoir.

2- As more oil is produced, more reservoir data become available, which could change or modify the initial estimate of the OOIP.

3- New developments and improvements in recovery and production methods may increase the possible recovery factor. Therefore, the proven reserve of any field is continuously updated.

EX} Calculate the initial oil-in-place (IOIP) and the proven reserve of an oil reservoir if A=1600 acres, h= 32 ft, ϕ=22%, S_w=20%, B_o = 1.23 RB/STB & R_f = 0.81.

Soln)

$$V_o = \frac{7758\ Ah\ \Phi\ (1-S_w)}{B_o}$$

$$= \frac{7758*1600*32*0.22\ (1-0.2)}{1.23} = 56836495.6 \text{ STB.}$$

R_f = proven reserve/ initial oil-in-place

So that proven reserve = R_f * IOIP = 0.81* 56836495.6 = 46.37561.4 STB.

EX} A well is draining a gas–water reservoir. The drainage area of the well is 160 acres and has a net thickness of 20 ft. Initial properties are 15% porosity, 30% water saturation, and gas FVF of 0.0016 RB/SCF. What was the original gas in place in the drainage area?

$$V_o = \frac{7758\ Ah\ \Phi\ (1-S_w)}{B_o}$$

$$= \frac{7758*160*20*0.15\ (1-0.3)}{0.0016} = 1.63 * 10^9 \text{ SCF.}$$

EX} Gas Recovery, the original gas in place (OGIP) of a gas reservoir is 5 trillion ft^3 (TCF). How much gas can be recovered (in TCF) if recovery from analogous fields is between 70 and 90% of OGIP?

Soln) Two estimates are possible: a lower estimate and an upper estimate.

The lower estimate of gas recovery is 0.70 *5 TCF = 3.5 TCF.

The upper estimate of gas recovery is 0.90* 5 TCF = 4.5 TCF.

EX} In a field, the porosity is 6% and the water saturation is 25%. The formation is 30 ft thick. What is the original oil in place in STB in a square mile? The oil formation volume factor is 1.5 RB/STB.

$$V_o = \frac{7758\, Ah\, \Phi\, (1-S_w)}{B_o}$$

$$= \frac{(5280\ \text{ft})^2 (30\ \text{ft})(0.06)(1-0.25)}{1.5\ \text{RB/STB}} \frac{1\text{bbl}}{5.6148\ \text{ft}^3} = 4468647.15\ \text{STB}$$